NOνA-NOTE-DET-58
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# NOνA Rigid PVC Flammability Testing and other Fire Related Issues

## Description of proposed apparatus

The amounts of various materials are still changing from the Appendix B description, and the current scheme would probably be more like 15.4 m wide by 15.4 m high by 114 m long, made of 32-cell wide PVC extrusions all epoxied together into one large plastic construct inside one large building. The extrusions form a honeycomb-like structure with one layer of horizontal cells followed by another layer of vertical cells and so on. The building would have a 25 m extension on one end for deliveries via truck. There might be as many as eight 15,000 gallon storage tanks inside to buffer the scintillator oil during a 2 to 4 year construction period.

Each 32-cell structure is 5.1 cm thick and 127 cm wide (and of course 1540 cm long) with 3mm thick exterior walls and 2mm thick interior webs. Each extrusion would hold about 720 kg of scintillator oil and all 32 cells are connected together for oil filling, so this is the minimum unit of oil.

The reduction in height/width from 17.5m in Appendix B just makes the parts (50' long + ends now) fit on a standard 53' trailer. The thicker walls are the result of our mechanical FEA analyses, which leads us to limit the stress in the plastic to 1000 psi maximum when under load from the liquid scintillator. The liquid scintillator load is now at 19 psi on the walls at the bottom of vertical cells.

## Composition of Rigid PVC.

**Rigid PVC** – 5,740 metric tons

This contains 15% titanium dioxide, perhaps 5% acrylic impact modifiers, perhaps 3% calcium carbonate, perhaps 3% of an organo-tin compound (e.g. methyltin mercaptide stabilizers), and apparently 1% lubricants (waxes)

## UL 94 flammability Test:

The samples of PVC extrusion provided passed our unofficial UL 94 flammability testing with a rating of UL 5VA or 5VB. This means the samples were subjected to a flame ignition source that is approximately five times more severe than that used in the HB, V-0, V-1 and V-2 tests, and the specimens may not drip any flaming particles. An explanation of the tests is in Appendix 1.

**Additional Burn Tests:**

While the UL 94 tests as well as the simple test of applying a torch are a good indication of the Rigid PVC flammability I wanted to perform a test that included the material subjected to heat and deferring flame sources with a thin film of the Liquid Scintillator "BICRON" sprayed on the interior and exterior of the PVC extrusion. Separate tests were conducted on the BICRON BC-517L liquid scintillator material to confirm its flammability, flash point etc.

1. First a propane torch was exposed to the vertical corner of the PVC for 15sec. It did not ignite. This test was much more severe than that used in the UL 5VA or %VB tests.
2. Next BC-517L liquid scintillator was sprayed on the surface and interior of the PVC extrusion and subjected to various heat and flame exposure to the extrusion somewhat real exposure overheating equipment, low energy flame and high-energy torch.
3. The following photos show the sample PVC subjected to 15 minutes of 690 F of a heat gun, a candle, low energy propane torch and a high-energy propane torch.

## Conclusions:

1. The PVC compounded with the formulation of 15% titanium dioxide, perhaps 5% acrylic impact modifiers, perhaps 3% calcium carbonate, perhaps 3% of an organo-tin compound (e.g. methyltin mercaptide stabilizers), and apparently 1% lubricants (Waxes). Does not ignite or become flammable or drip material when subjected to various ignition sources and contaminated with the BC-517L.
2. The PVC when exposed to high temperatures point sources will form pinholes, spraying the BC-517L under pressure onto surrounding surfaces. Further testing under pressure is recommended.
3. The BC-517L will ignite in a sprayed filmed condition if exposed to the right ignition source.
4. The flammability of the **Wavelength shifting optical fiber** was not tested or **Hamamatsu 16 channel Avalanche Photodiodes** were not tested. It is recommended they be tested in a configuration simulator to exposure to the BC-517L .
**(Wavelength shifting optical fiber** The fiber is mostly a fluor-doped polystyrene core, clad in a thin acrylic intermediate layer, then on the outside clad in a thin polyfluor .
**Hamamatsu 16 channel Avalanche Photodiodes 856,000 channels of electronics** using Hamamatsu 16 channel Avalanche Photodiodes.
These "APDs" get about 400 volts applied and are thermo-electrically cooled to -10 degrees C. The thermo-cooler is probably the biggest heat load, maybe 40 watts for 64 channels – still, that's 500 kW distributed in perhaps 50,000 spots over the top and one long side of the detector.)

5. The BC-517L was not easily ignitable from exposure to a 690 F heat gun, a low energy flame, or a candle on the interior or exterior of the PCV extrusion.

6.Ignition of the BC-517L occurred on exposure to only a high-energy flame or BC-517L reached ~50C at which I suspect the pseudocumene was igniting in the mixture.

**7.** It is important that the compounding of the PVC be documented and changes will require additional testing. In a future test the PVC will be tested under pressure in a fire situation with the BC-517L and the Wavelength optical fiber and the Hammamatsu Photodiodes. .

## Additional testing might include the following tests.

- ASTM D2863 Oxygen Index, 3 mm x 6 mm x 100 - 150 mm - 10 specimens
- ASTM D568 Flammability of Plastics - Vertical Burn Test, 450 mm x 25 mm - 10 specimens
- ASTM D635 Flammability of Plastics - Horizontal Burn, 125 mm x 12.5 mm - 10 specimens
- ASTM E659 Autoignition Temperature of Liquid Chemicals, 100ml
- ASTM E681 Limits of Flammability of Chemicals, 250ml
- 2-Foot Tunnel Screening test for surface flammability of materials, 3.75” x 23.75”

**Fire Detection and Suppression Recommendations.**

1. All electronic racks should be equipped with smoke detection to shut down rack electronics. A VESDA or similar system should be installed for early warning and shut down of electronics and power on high alarm.

2. A suppression system of either dry chemical and or non-alcohol foam should be installed and zoned as to discharge to the fire area. Fighting the fire using normal sprinklers or fire department hand lines ineffective and will cause a problem of containment and run off.

3. The containment for a leak caused by a fire should be figured at a minimum of 10% of the surrounding 32 cells to the fire. This is only a guess at this point.

4. A model of fire Plume and Area of impact should be developed to aid in the analyzing a vast quantity of air, water, soil soot developed during a fire. This should include the following for the by products that will be produced from a fire of BC –517L and PVC and scintillator materials and possible by products which could include:

**4.1 Benzene and other VOCs and Metals, Dioxins /Furans, Hydrogen Chloride, PAHs, Soot.**

a. General Description
b. Monitoring Description
c. Standard /Guidelines and Interpretation
d. Follow up Advise/

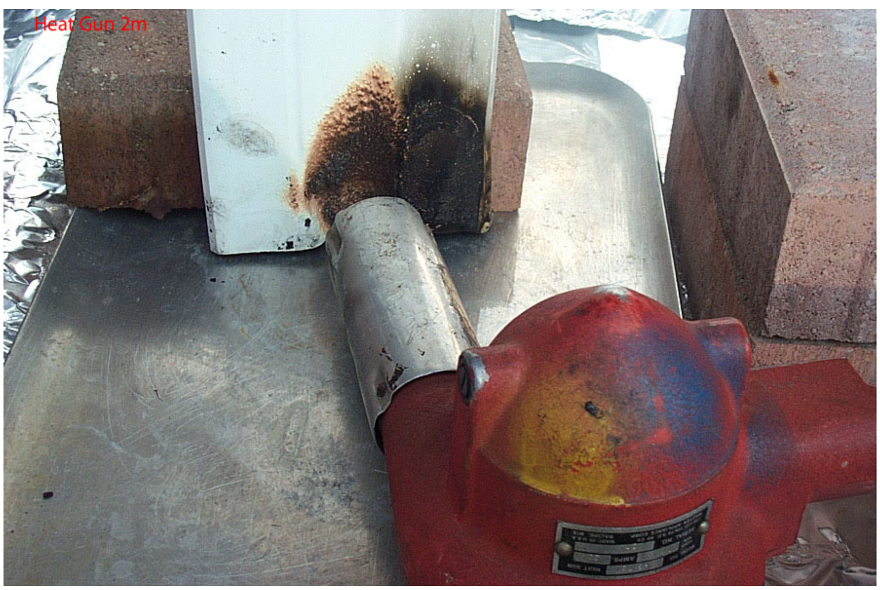
**4.2 Additional studies should be considered for**

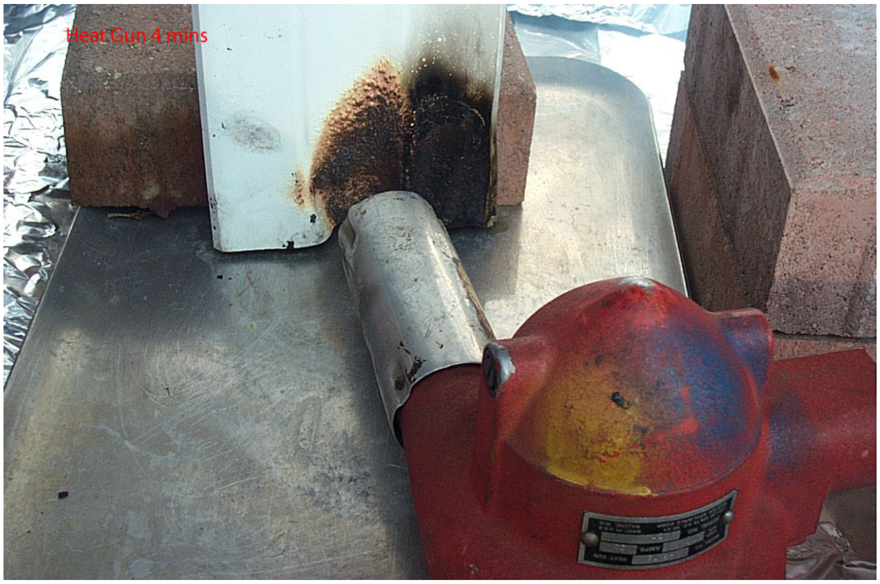
a. **Soot:**
Definition
Dioxins or other toxins in soot
Metals in Soot

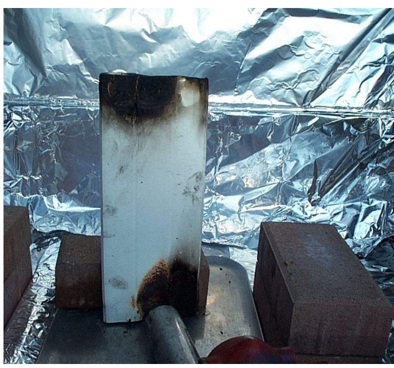
b. **Surface Water Quality and Aquatic Toxicity Testing**
Fate of Water at the site
Monitoring Description
Site Runoff from fire

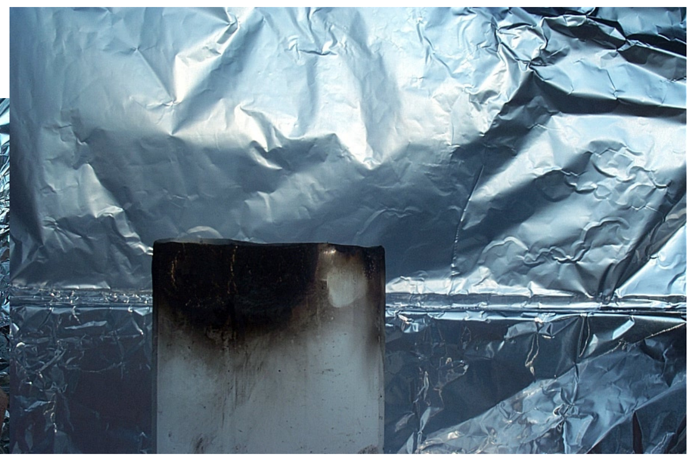
c. **Aquatic Toxicity Test. (Bioassays)**

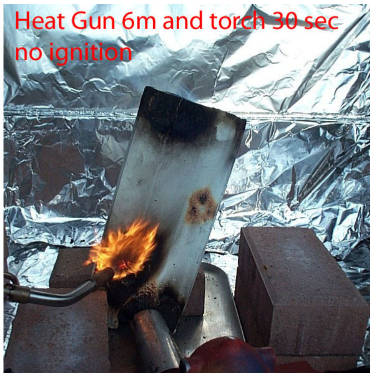
# Test Photos

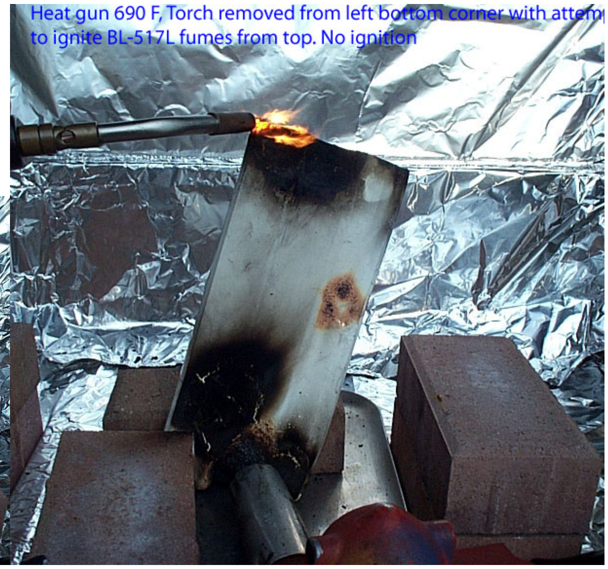


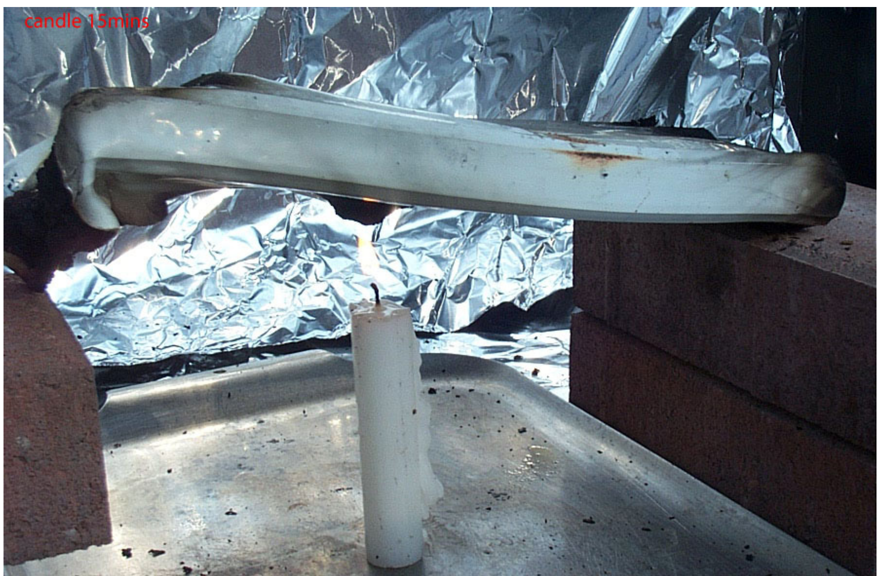

Heat Gun 4 mins

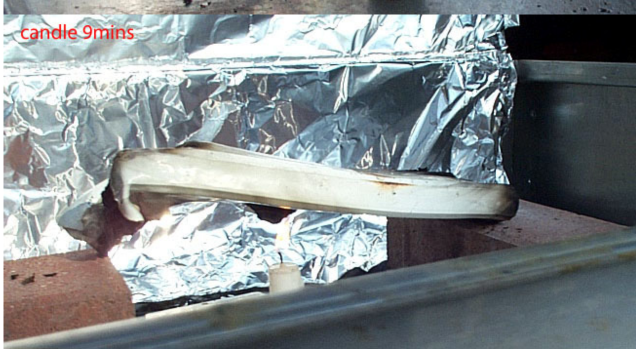


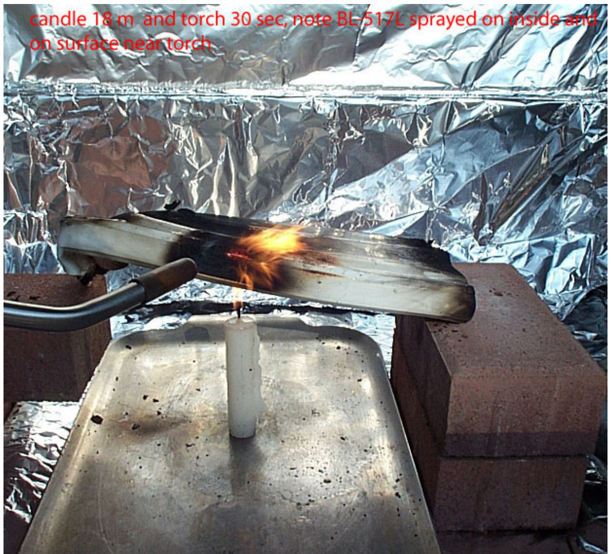



Heat Gun 6m and torch 30 sec
no ignition

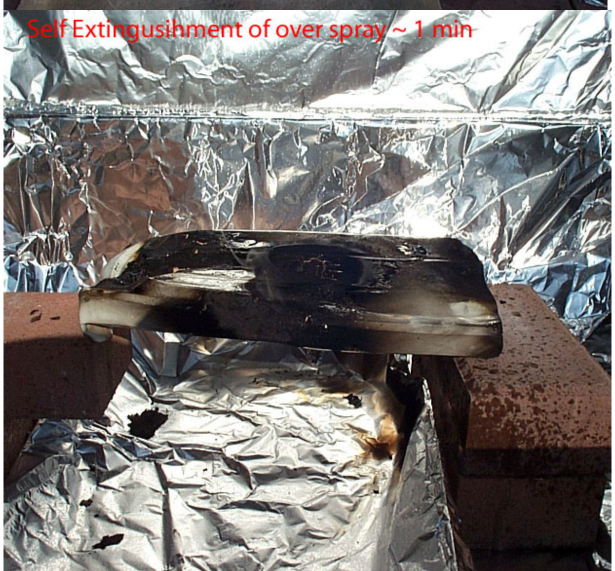

Heat gun 690 F, Torch removed from left bottom corner with attem
to ignite BL-517L fumes from top. No ignition


candle 15mins

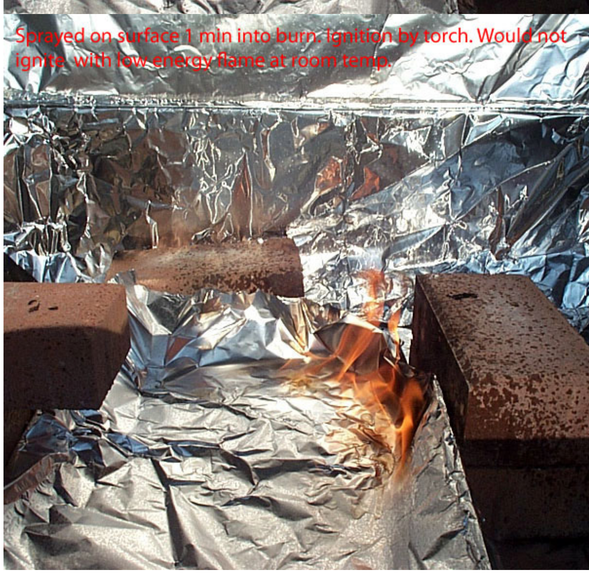

candle 9mins



candle 18 m and torch 30 sec, note BL 517L sprayed on inside and on surface near torch

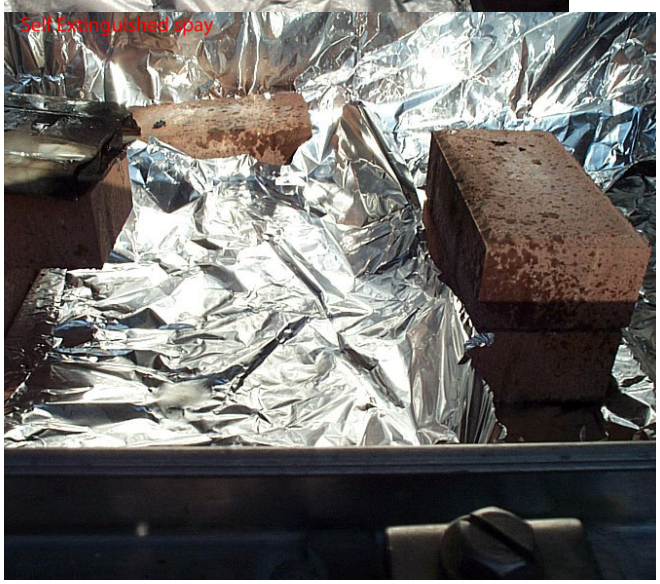


Self Extingusihment of over spray ~ 1 min



Sprayed on surface 1 min into burn. Ignition by torch. Would not ignite with low energy flame at room temp.


flame on sprayed on surface at 5m, note ignition by torch
would not ignite with low energy flame.


Self Extinguished spay

Appendix 1

# UL 94 flammability testing

There are two types of pre-selection test programs conducted on plastic materials to measure flammability characteristics. The first determines the material's tendency either to extinguish or to spread the flame once the specimen has been ignited. The first program is described in UL 94, The Standard for Flammability of Plastic Materials for Parts in Devices and Appliances, which is now harmonized with IEC 60707, 60695-11-10 and 60695-11-20 and ISO 9772 and 9773.

The second test program measures the ignition resistance of the plastic to electrical ignition sources. The material's resistance to ignition and surface tracking characteristics is described in UL 746A, which is similar to the test procedures described in IEC 60112, 60695 and 60950.

## UL 94 flame classifications

There are 12 flame classifications specified in UL 94 that are assigned to materials based on the results of these small-scale flame tests. These classifications, listed below in descending order of flammability, are used to distinguish a material's burning characteristics after test specimens have been exposed to a specified test flame under controlled laboratory conditions.

- Six of the classifications relate to materials commonly used in manufacturing enclosures, structural parts and insulators found in consumer electronic products (5VA, 5VB, V-0, V-1, V-2, HB).
- Three of the remaining six classifications relate to low-density foam materials commonly used in fabricating speaker grills and sound-deadening material (HF-1, HF-2, HBF).

- The last three classifications are assigned to very thin films, generally not capable of supporting themselves in a horizontal position (VTM-0, VTM-1, VTM-2). These are usually assigned to substrates on flexible printed circuit boards.

## Horizontal versus vertical positioning

Specimens molded from the plastic material are oriented in either a horizontal or vertical position, depending on the specifications of the relevant test method, and are subjected to a defined flame ignition source for a specified period of time. In some tests, the test flame is only applied once, as is the case of the horizontal burning (HB) test, while in other tests the flame is applied twice or more.

A HB flame rating indicates that the material was tested in a horizontal position and found to burn at a rate less than a specified maximum.

The three vertical ratings, V2, V1 and V0 indicate that the material was tested in a vertical position and self-extinguished within a specified time after the ignition source was removed. The vertical ratings also indicate whether the test specimen dripped flaming particles that ignited a cotton indicator located below the sample. UL 94 also describes a method in which the test flame is applied for up to five applications, in testing for a 5VA or 5VB classification. These small-scale tests measure the propensity of a material to extinguish or spread flames once it becomes ignited.

## Difference in test methods and criteria

When looking at the flame ratings for plastic materials commonly molded to fabricate enclosures, structural parts and insulators found in consumer electronic products (5VA, 5VB, V-0, V-1, V-2 and HB), a material classified as 5VA or 5VB is subjected to a flame ignition source that is approximately five times more severe than that used in the HB, V-0, V-1 and V-2 tests, and the specimens may not drip any flaming particles. The three remaining six classifications specified in UL 94 relate to low-density foam materials commonly used in fabricating speaker grills and sound-deadening material (HF-1, HF-2, HBF). The remaining three classifications are assigned to very thin films, generally not capable of supporting themselves in a horizontal position (VTM-0, VTM-1, VTM-2).

## UL 746A ignition tests

In addition to flammability considerations, a material's ability to resist ignition from electrical sources is another important factor that must be considered in the selection and evaluation of a material for use in electrical equipment. Possible electrical ignition sources in equipment are: overloaded (overheated) electrical conductors and components; arcing parts, such as the open contacts of switches and relays; and arcing at broken or loose connections, e.g., splices or terminals. Polymeric materials in direct contact with or in close proximity to overloaded or arcing electrical parts could ignite.

The three basic tests used to evaluate a material's ability to resist ignition are the Hot-Wire Ignition (HWI) High-Current (or High-Amp) Arc Ignition (HAI); and High-Voltage Arc Tracking Rate (HVTR). Details of the test criteria can be found in UL 746A, The Standard for Polymeric Materials - Short-Term Evaluations. The Recognized Component Directory tabulates the results of the small-scale tests conducted on the materials.

The HWI test indicates a material's resistance to ignition when exposed to abnormally high temperatures resulting from a component failure, such as a conductor carrying far more than its rated current. HWI performance is expressed as the mean number of seconds required to ignite a specimen when wrapped with an energized ni-chrome resistive wire that dissipates a specified level of energy.

The HAI test determines the material's ability to withstand electrical arcing either directly on or just above the surface of the plastic material. This can occur in the presence of open switch contacts or in the event of the failure of an electrical connection. HAI performance is expressed as the number of arc rupture exposures -- using standardized electrode materials, geometry and electrical supply circuit -- required to ignite a specimen when the arc occurs directly on the surface or a specified distance above the test specimen.

The HVTR for a material is expressed as the rate (in inches per minute) that a tracking path can be produced on the surface of the material under standardized test conditions. This test relates to establishment of an electrically conductive path on the surface of a solid, insulated material as a result of electrical stress.

Another ignition test can be applied to measure a material's resistance to ignition property. This test is the Glow-Wire Ignitability Test and is also described in UL 746A and 746C, Polymeric Materials - Use in Electrical Equipment Evaluations.

The method is based on a test procedure that is documented in IEC 60695 and specified in numerous IEC end-product specifications, including IEC 60335-1.

The test is somewhat similar to the HWI test in that it measures a material's resistance to ignition on application of a heated non-flaming source.